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SOLAR HEATING AND COOLING  
TECHNICAL DATA AND SYSTEMS ANALYSIS

PRESENTATION CHARTS

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# Center for Environmental and Energy Studies

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The University  
Of Alabama  
In Huntsville

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SEPTEMBER 1975



(NASA-CR-144111) SOLAR HEATING AND COOLING:  
TECHNICAL DATA AND SYSTEMS ANALYSIS.  
PRESENTATION CHARTS (BRIEFING TO NASA 17  
SEPTEMBER, 1975) Interim Status Report,  
Oct. 1974 - Aug. 1975 (Alabama Univ.,

N76-15588

Unclassified  
G3/44 57450

SOLAR HEATING AND COOLING  
TECHNICAL DATA AND SYSTEMS ANALYSIS

PRESENTATION CHARTS  
(Briefing to NASA September 17, 1975)

CONTRACT NAS8-31293

Submitted to

National Aeronautics & Space Administration  
Marshall Space Flight Center, Alabama

(Summary for Period October 1974 - August 1975)

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE  
CENTER FOR ENVIRONMENTAL AND ENERGY STUDIES  
HUNTSVILLE, ALABAMA

SEPTEMBER 1975

## INTRODUCTION

This presentation was given to the NASA Marshall Space Flight Center on September 17, 1975 as part of an interim status report on Contact NAS8-31293. In addition, certain overall considerations concerning the contract effort were presented by UAH. These considerations included systems planning, methodology and procedures which might be applied to the current program. Projected activities including computer modeling, management information systems, educational and public awareness programs and overall capabilities and goals of The UAH Center for Environmental and Energy Studies were made at a later but related briefing held on October 22, 1975.

Attendees at the September 17 briefing were:

### UAH Attendees

J. David Woody  
Sang Bai  
Stephen C. Vavra  
Nancy Hill  
Sudesh Malhotra  
Arvind Patel  
E. A. Carter  
Richard D. MacDiarmid  
D. L. Christensen

### NASA-MSFC

Stanley Wade  
Joseph W. Hamaker  
George D. Hopson  
Wayne Littles  
R. L. Middleton  
J. F. Pavlick  
C. M. Akridge  
D. R. Bowden  
William Richardson  
Robert M. Gunner  
D. L. Smith

### Other

John Short  
Klaus Bergeler

SOLAR HEATING AND COOLING  
TECHNICAL DATA AND SYSTEMS ANALYSIS

RESEARCH STUDY FOR NASA  
CONTRACT NUMBER NAS8-3I293  
STARTED OCTOBER 1974

2  
STATUS REPORT  
THROUGH SEPTEMBER 1975

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE  
SCHOOL OF GRADUATE STUDIES AND RESEARCH  
CENTER FOR ENVIRONMENTAL AND ENERGY STUDIES

## PRESENTATION OUTLINE

INTRODUCTION AND OVERVIEW

D. L. CHRISTENSEN  
PRINCIPAL INVESTIGATOR

CLIMATIC DATA

E. CARTER

EQUIPMENT DATA

R. MACDIARMID

ECONOMIC DATA

D. WOODY

ARCHITECTURAL DATA

D. CHRISTENSEN

SYSTEMS DATA

D. CHRISTENSEN

OVERALL CONSIDERATIONS

D. CHRISTENSEN

SUMMARY

D. CHRISTENSEN

## PROGRAM OBJECTIVES

- PROVIDE RESEARCH SUPPORT TO MSFC SOLAR TASK TEAM
- DETERMINE STATE-OF- ART IN SOLAR ENERGY HEATING AND COOLING
- IDENTIFY SOURCES OF RELATED INFORMATION AND ACQUIRE NEEDED DATA
- DEVELOP DATA PACKAGES IN SELECTED AREAS
- PROVIDE FORMATS AND INPUTS FOR THE SYSTEMS ANALYSIS DATA BANK  
(NASA-MSFC)
  - ARCHITECTURAL
  - SITE CONDITIONS
  - MATERIALS
  - CLIMATIC
  - EQUIPMENT
  - ECONOMIC

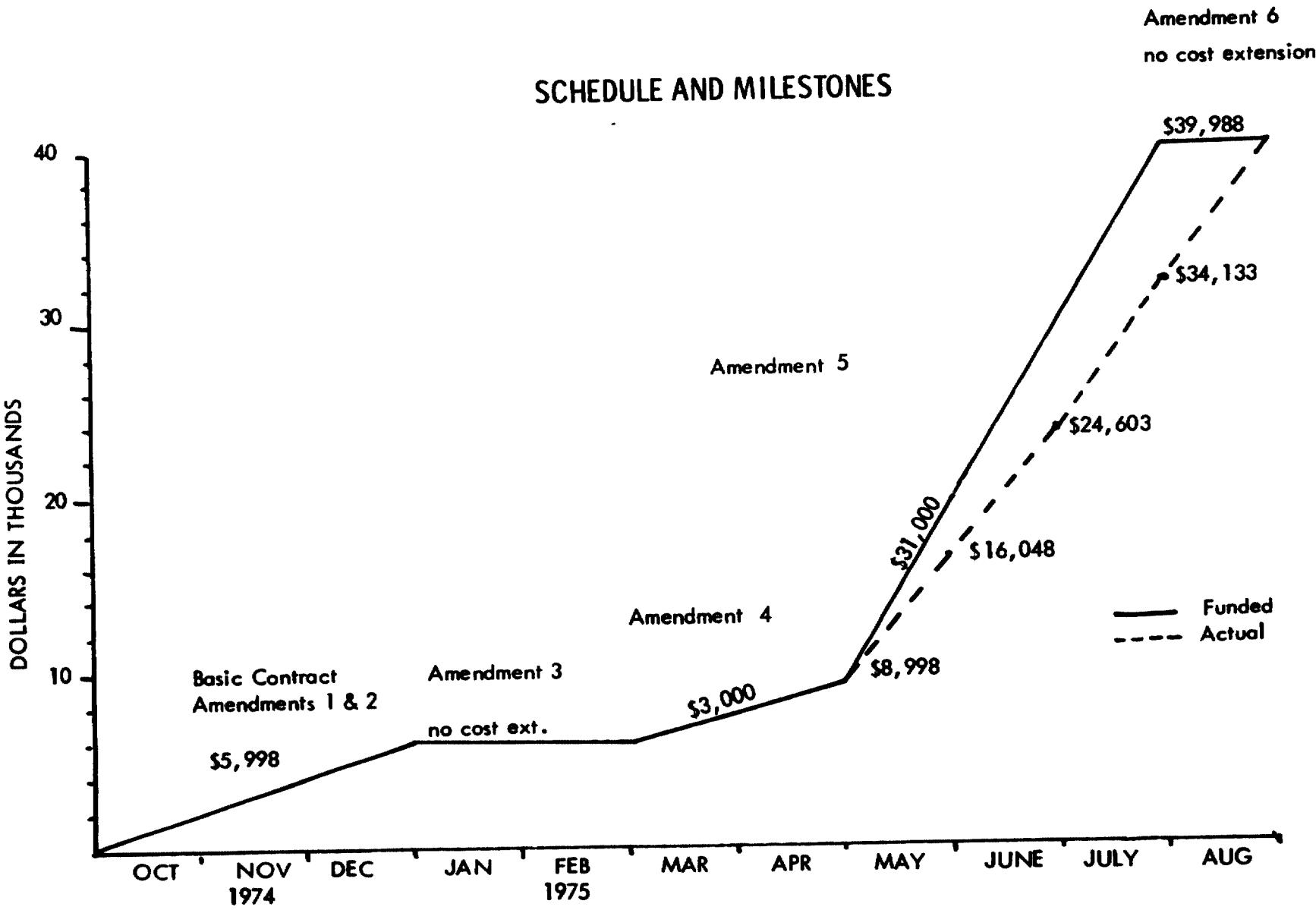
COMPLETED TASKS  
(AMENDMENTS 1-4, 9K)

- DEVELOPED PRESENTATION MATERIAL (DATA PACKAGES, SLIDES, CHARTS, VISUALS)
- COMPILED SOLAR ENERGY DATA SOURCE LISTS
- COMPILED SOLAR COLLECTOR DATA BOOK (96 FIRMS IDENTIFIED, 48 REPLIES RECEIVED)
- PERFORMED SURVEY OF SOLAR HEATING AND COOLING SYSTEMS (137 PROJECT LOCATIONS, 50 REPLIES RECEIVED)
- SEMINARS AND CONSULTANT SUPPORT (LÖF AND DUFFIE)
- RESEARCH, LIAISON AND COORDINATION ACTIVITIES
- DEVELOPED BIBLIOGRAPHIES AND SOURCE MATERIALS
  - DATA BANKS
  - MATERIALS AND COATINGS
  - SOLAR WATER HEATERS
- PREPARED LETTER PROGRESS REPORTS

COMPLETED TASKS  
(AMENDMENTS 5 & 6, 3IK)

- DEVELOPED DETAILED MIRADS COMPUTER FORMATS FOR PRIMARY DATA PARAMETERS (NATIONWIDE)
  - CLIMATIC
  - ARCHITECTURAL
  - SITE (TOPOGRAPHY)
  - HEATING AND COOLING EQUIPMENT (CONVENTIONAL AND SOLAR)
  - THERMAL LOADS
  - ECONOMIC (ENERGY AND GEOGRAPHIC)
- IDENTIFIED AND CONTACTED DATA SOURCES IN EACH OF ABOVE AREAS
- IDENTIFIED AND CONTACTED 40 NEW SOLAR RADIATION DATA STATIONS (FORMAL LISTING BEING PUBLISHED)
- ACQUIRED, PROCESSED, AND HOLDING CATALOGS, REPORTS, SCHEDULES, COMPUTER PROGRAMS, WEATHER DATA, QUESTIONNAIRES, ETC. FOR ENTRY INTO MIRADS
- PREPARED OVERALL PROGRESS REPORT AND BRIEFING MATERIAL

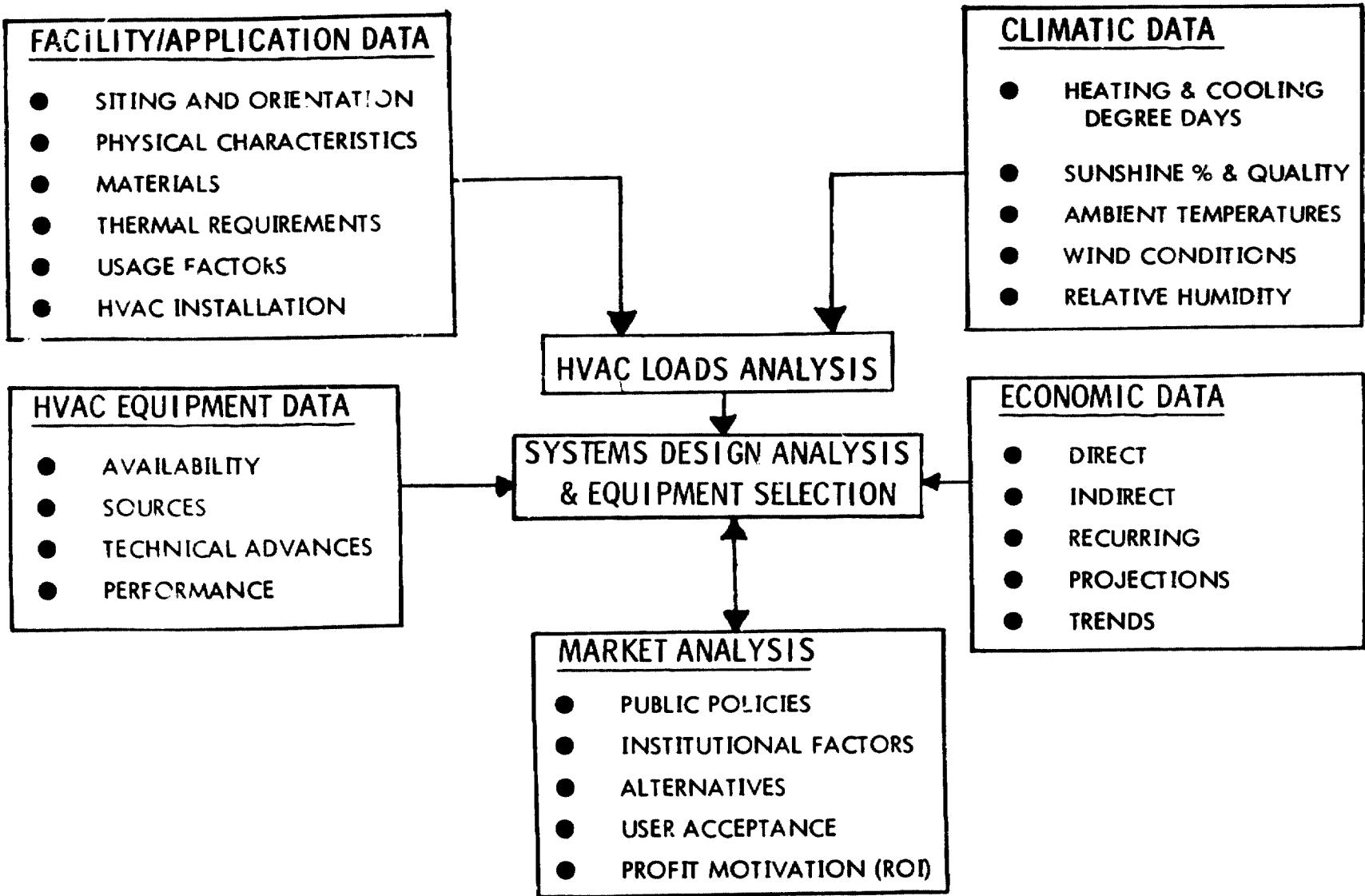
## SCHEDULE AND MILESTONES



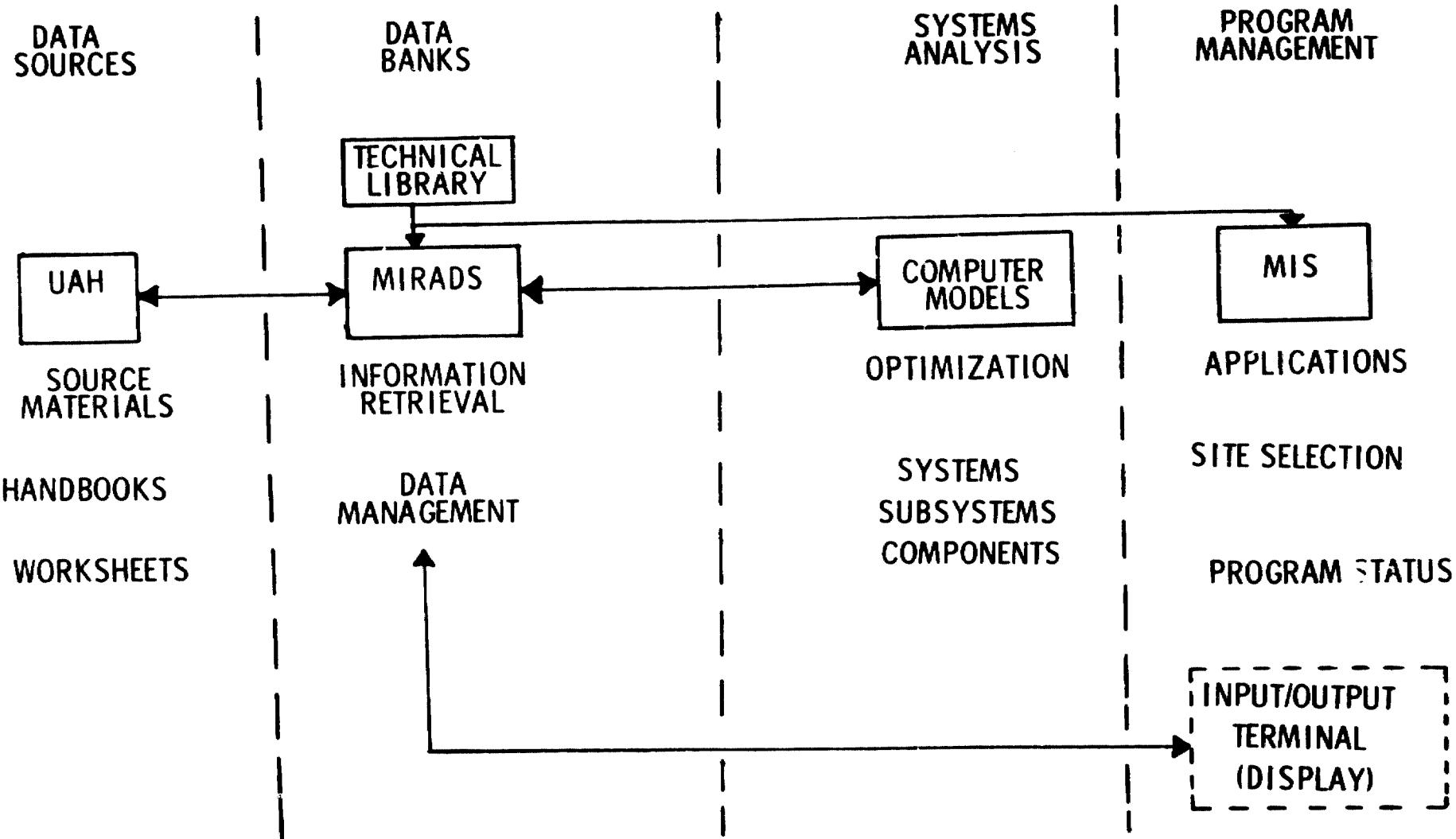
## ASSIGNED TASKS (AMENDMENT 7, 40K)

- ENTER ACQUIRED DATA INTO FORMAT SHEETS
- IMPROVE AND UPDATE FORMAT SHEETS
- IDENTIFY AND ACQUIRE DATA FROM NEW SOURCES
  - NEW MANUFACTURERS
  - NEW EQUIPMENT PERFORMANCE CHARACTERISTICS
  - IMPROVED TECHNIQUES
- OTHER TASKS AS ASSIGNED

## DATA REQUIREMENTS



## DATA FLOW DIAGRAM



## CLIMATIC - ACCOMPLISHMENTS

- DEVELOPED AND SUBMITTED DATA FORMAT SHEETS
- SENT LETTERS TO PROSPECTIVE DATA SOURCES
- ACQUIRED NWS SOLAR RADIATION DATA TAPES
  - 41 STATIONS WITH DAILY VALUES
  - 19 STATIONS WITH DAILY & HOURLY VALUES
  - 26 COOPERATING STATIONS WITH DAILY VALUES
- ACQUIRED DATA TAPES - MADISON, WISCONSIN
- ACQUIRED DATA TAPES - NASHVILLE, TENNESSEE
- ACQUIRED MONTHLY & ANNUAL CLIMATOLOGICAL DATA SHEETS: NASHVILLE AND MADISON
- LOCATED 21 OTHER SOLAR RADIATION RECORDING SITES
- LOCATED 12 SITES FOR SPECIAL PURPOSES

## CLIMATIC - RECOMMENDATIONS

- EVALUATE LOCATED DATA
  - APPLICABILITY TO MSFC PROJECT
  - AVOID DUPLICATED EFFORTS
  - ESTABLISH COLLECTION PRIORITIES
- COLLECT ADDITIONAL DATA
- QUALITY CONTROL - VALIDATE
- ORGANIZE FOR DATA BANK

## EQUIPMENT - ACCOMPLISHMENTS

- DEVELOPED (INTERACTIVE) MATRICES (CONVENTIONAL & SOLAR HVAC EQUIPMENT)
- DEVELOPED AND SUBMITTED DATA FORMATS
- IDENTIFIED AND CONTACTED 150 SOLAR ENERGY PROJECT APPLICATIONS
- 100 SOLAR COLLECTOR MANUFACTURERS CONTACTED AND DATA COLLECTED
- IDENTIFIED AND CONTACTED MANUFACTURERS OF SOLAR ENERGY EQUIPMENT CONTROLS
- DATA ACQUISITION METHODS
  - IDENTIFY SOURCES
  - CONTACT BY TELECON OR MAIL
  - FOLLOW UP FOR ADDITIONAL DATA
- ACQUIRED STANDARDS DATA FROM VARIOUS ASSOCIATIONS & SOCIETIES
- INVESTIGATING INDUSTRY TRENDS - STANDARDS AND EFFICIENCIES
  - DOMESTIC WATER HEATING
  - AIR CONDITIONING
  - COMBUSTION SYSTEMS

# ENERGY SOURCES AND EQUIPMENT FOR HEATING, VENTILATION AND COOLING (HVAC)

	ENERGY SOURCES	HEATING CONVERSION SUBSYSTEMS	CONTROLS SUBSYSTEM	THERMAL STORAGE SUBSYSTEM	COOLING CONVERSION SUBSYSTEM	FLUID DISTRIBUTION (VENTILATION)
CONVENTIONAL HVAC SYSTEMS	<p><u>Utility Sources</u></p> <ul style="list-style-type: none"> <li>• Electricity (Line)</li> <li>• Gas (Line)</li> <li>• District Steam</li> <li>• District chilled water</li> </ul> <p><u>On Premise Storage</u></p> <ul style="list-style-type: none"> <li>• Oil (Tank)</li> <li>• LPG (Tank)</li> <li>• Coal</li> <li>• Wood</li> </ul> <p><u>Prime Mover</u></p> <p><u>Standby Power</u></p>	<p><u>Boilers</u></p> <p><u>Furnaces</u></p> <p><u>Radiant Heaters</u></p> <p><u>Unit Heaters</u></p> <p><u>Heat Pumps</u></p>	<p><u>On - Off</u></p> <p><u>Modulated</u></p> <p><u>Hybrid</u></p>	<p>Domestic Hot Water Tank</p>	<p><u>Absorption</u></p> <p><u>Compression</u></p> <p><u>Dehumidification</u></p> <p><u>Evaporative</u></p> <p><u>Heat Pumps</u></p>	<p><u>Ducting</u></p> <ul style="list-style-type: none"> <li>• Ducts</li> <li>• Plenums</li> <li>• Blower/ Motors</li> <li>• Diffusers</li> </ul>
SOLAR HVAC SYSTEMS	<p><u>Solar Insolation</u></p> <ul style="list-style-type: none"> <li>• Diffuse Radiation</li> <li>• Direct Radiation</li> </ul> <p><u>Conventional Sources</u></p> <ul style="list-style-type: none"> <li>• Auxiliary Equip.</li> </ul>	<p><u>Solar Collectors</u></p> <ul style="list-style-type: none"> <li>• Flat Plate</li> <li>• Concentrating</li> <li>• Structural</li> </ul> <p><u>Auxiliary Equip.</u></p> <ul style="list-style-type: none"> <li>• Conventional</li> </ul>	<p>Unique to Solar HVAC</p>	<p><u>Sensible Heat</u> (Specific Heat)</p> <p><u>Latent Heat</u> (Heat of Fusion)</p>	<p>Unique to Solar Cooling</p>	<p><u>Piping</u></p> <ul style="list-style-type: none"> <li>• Pipes/Tubes</li> <li>• Pipes/Motors</li> </ul> <p><u>Terminal Devices</u></p> <ul style="list-style-type: none"> <li>• Heat Exchangers</li> </ul>

## SOLAR SUBSYSTEMS

	SOLAR COLLECTOR	THERMAL STORAGE	HEAT ACTUATED AIR CONDITIONER	SPACE HEATER	ENERGY TRANSPORT MEDIUM	AUXILIARY ENERGY	
	LOW-TEMP CONVENTIONAL FLAT PLATE WITH OUT CONCENTRATORS	LIQUID (WATER) PRESSURIZED UNPRESSURIZED	ABSORPTION CYCLES	LIQUID TO AIR HEAT EXCHANGER	LIQUID		
	LOW - TEMP CONVENTIONAL FLAT PLATE WITH CONCENTRATOR	SOLIDS (STONE) (BRICK, ETC.)	MECHANICAL POWER RANKINE & STIRLING CYCLES	SOLID AIR HEAT EXCHANGE (HEAT PIPE)	AIR		
	LOW - TEMP VACUUM FLAT PLATE	PHASE CHANGE MATERIALS	DEHUMIDIFYING (DESSICANT CYCLING)	VAPOR TO AIR HEAT EXCHANGER (HEAT PIPE)	VAPOR (HEAT PIPE)		
	DIRECT WATER EXPOSURE DAY HEAT NIGHT COOL	HYBRID SYSTEMS (PHASE CHANGE) LIQUIDS & SOLIDS	OTHER	RADIANT HEAT	OTHER		
	HIGH - TEMP POINT OR LINE CONCENTRATOR	OTHER		OTHER			

## EQUIPMENT RECOMMENDATIONS

- ACCELERATE DATA INPUT TO MIRADS
  - SOLAR COMPONENTS, SUB SYSTEMS, SYSTEMS
  - CONVENTIONAL EQUIPMENTS
- CONTINUE ACQUISITION OF DATA ON
  - SOLAR EQUIPMENTS
  - CONVENTIONAL EQUIPMENTS
- GATHER & STUDY COST COMPARATIVE DATA TO
  - EVALUATE VALIDITY
  - IMPROVE TECHNIQUES
- INITIATE A "NEAR FUTURE PROJECT SURVEY" OF INDUSTRY TO EVALUATE TRENDS MORE OBJECTIVELY
- CONSTRUCT A GENERALIZED APPROACH TO AN OVERALL SYNTHESIS AND EVALUATE EXISTING PROGRAMS AS TO APPLICABILITY
- INITIATE A STUDY TO STREAMLINE EQUIPMENT COST SUMMATIONS

## ECONOMIC - ACCOMPLISHMENTS

- DEVELOPED AND SUBMITTED DATA FORMAT SHEETS
- CATALOGED STATISTICAL ABSTRACT INFORMATION
- SENT QUESTIONNAIRES TO SELECTED CHAMBERS OF COMMERCE
- ON MAILING LIST OF EACH STATE FOR LABOR STATISTICS
- DEVELOPED CONTACT WITH UNITED MINEWORKERS FOR COAL DATA
- SENT LETTERS TO UTILITIES COMPANIES, FEA, FPC, TVA, ETC.
- CATALOGED ALL DATA TO STATE LEVEL - SOME CASES TO CITY LEVEL

## ECONOMIC - RECOMMENDATIONS

- DATA FORMAT FLEXIBILITY NEEDED FOR CHANGING INFORMATION
  - EMPLOYMENT DATA
  - CHAMBER OF COMMERCE DATA
- GUIDELINES NEEDED FOR DATA UPDATING METHODS
- GUIDELINES NEEDED FOR ECONOMIC DATA CHARGES
- STATISTICAL ABSTRACT TABLES INCORPORATED INTO DATA BANK

## ARCHITECTURAL - ACCOMPLISHMENTS

- DEVELOPED AND SUBMITTED DATA FORMAT SHEETS
  - RESIDENTIAL AND COMMERCIAL BUILDINGS
  - SITING AND ORIENTATION
  - MATERIALS THERMAL PROPERTIES
- TYPICAL SOURCES OF DATA
  - CARRIER TECHNICAL DEVELOPMENT PROGRAM, COOLING LOAD ESTIMATES
  - PROCEDURE FOR DETERMINING HEAT AND COOLING LOADS FOR COMPUTERIZED ENERGY CALCULATIONS
  - GUIDE FOR CALCULATION OF ELECTRIC SPACE HEATING AND COOLING
  - ASHRAE PROPOSED PROCEDURES FOR SIMULATING THE PERFORMANCE OF COMPONENTS AND SYSTEMS FOR ENERGY CALCULATIONS
  - ARCHITECTURAL GRAPHIC STANDARDS
  - HANDBOOK OF AIR CONDITIONING, HEATING AND VENTILATING

## ARCHITECTURAL - ACCOMPLISHMENTS (CONT'D)

- ENERGY SYSTEMS OPTIMIZATION PROGRAM
- COMPUTER PROGRAM FOR ANALYSIS OF ENERGY UTILIZATION IN POSTAL FACILITIES,
- SOUTHERN STANDARD BUILDING CODE
- EVALUATION OF HEATING LOADS IN OLD RESIDENTIAL STRUCTURES
- RESIDENTIAL ENERGY CONSUMPTION SINGLE HOUSING FINAL REPORT
- PROVIDED CONSTRUCTION MATERIAL COST DATA FOR HUNTSVILLE AREA (HUNTSVILLE SOLAR HOUSE ANALYSIS)

## ARCHITECTURAL RECOMMENDATIONS

- INCLUDE ARCHITECTURAL BASELINE DATA FROM EXISTING SOLAR ENERGY H & C DEMO PROJECTS IN DATA BANK
- USE AVAILABLE ASHRAE GUIDE FOR DESCRIBING THERMAL PROPERTIES OF CONSTRUCTION MATERIALS
- UTILIZE EXISTING MODELS FOR DEFINING BUILDING AND SITE PARAMETERS WHERE POSSIBLE
- FURTHER ANALYSIS AND SCREENING OF OVER 100 IDENTIFIED MODELS APPLICABLE TO BUILDING AND THERMAL LOADS IS REQUIRED

## DATA UTILIZATION FOR SYSTEMS ANALYSIS

- ALL COLLECTED DATA IS EVALUATED FOR PROJECT APPLICATION
- SYSTEMS APPLICATIONS AND EXISTING COMPUTER MODELS AND SIMULATIONS HAVE BEEN IDENTIFIED
- THESE NEED FURTHER ANALYSIS AND INTEGRATION INTO TOTAL PROGRAM REQUIREMENTS

## SELECTED COMPUTER MODELS FOR SOLAR ENERGY HEATING AND COOLING SYSTEMS

### GENERALIZED MODELS

TRNSYS - (UNIVERSITY OF WISCONSIN)

SOLSYS - (SANDIA LABORATORIES)

LASL - (LOS ALOMOS SCIENCE LABORATORIES)

### ECONOMIC ANALYSIS

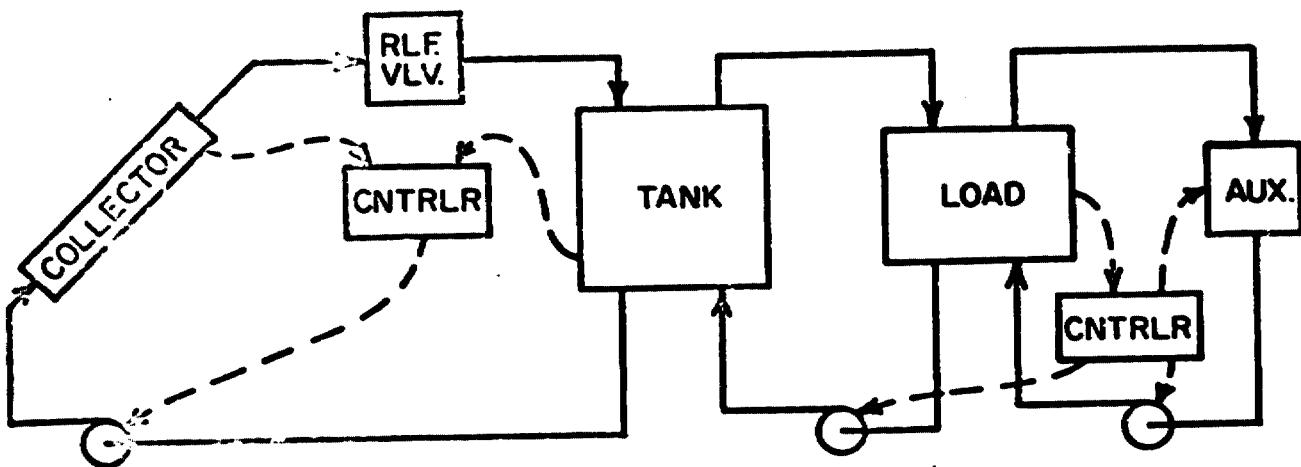
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SCC-ADL - (A. D. LITTLE, INC.)

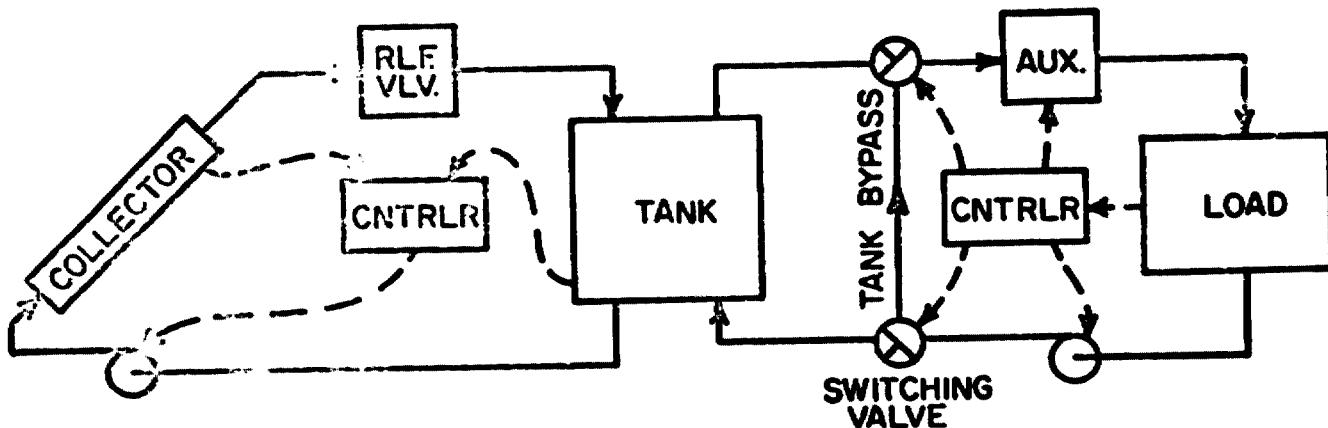
BUTZ - (UNIVERSITY OF WISCONSIN)

SIMSHAC - (COLORADO STATE UNIVERSITY)

## TYPICAL SCHEMATICS FOR COMPUTER MODELS



A) SYSTEM A. SPACE HEATING WITH "PARALLEL" AUXILIARY



B) SYSTEM B. SPACE HEATING WITH "SERIES" AUXILIARY

# SYSTEMS DEVELOPMENT PROCEDURE

## 1. STATEMENT OF NEED

## 2. STATE GOALS AND OBJECTIVES

## 3. STATE WHAT THE SYSTEM WILL DO

## 4. PERFORMANCE SPECIFICATIONS

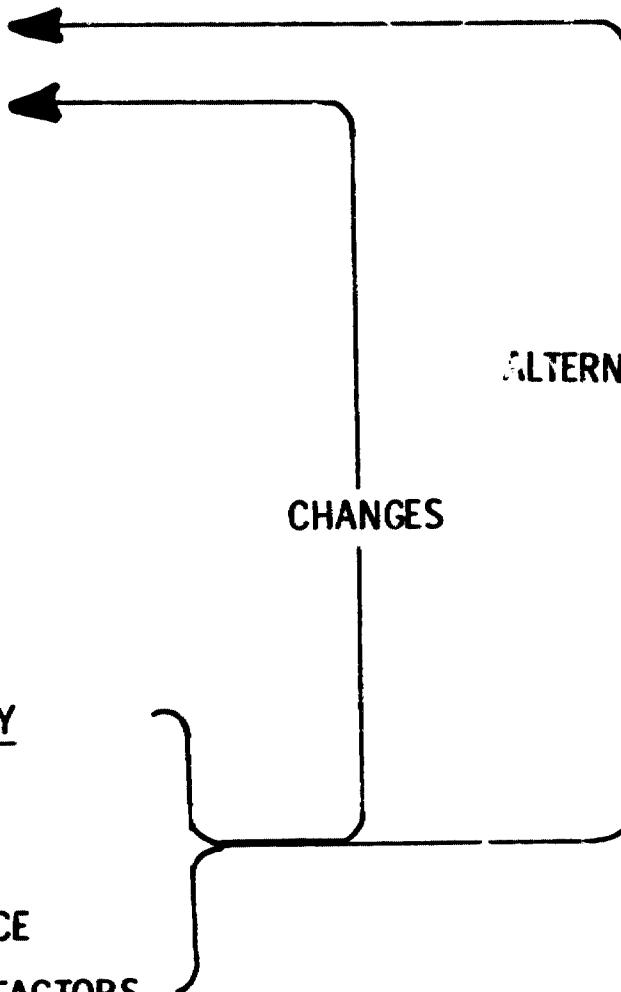
- EXPECTED OUTPUT
- REACTION TIMES
- RELIABILITY

## 5. DESIGN SPECIFICATIONS

- PROPOSED HARDWARE
- PROPOSED SOFTWARE
- COST OF SYSTEM
- SCHEDULES

## 6. GENERAL FEASIBILITY

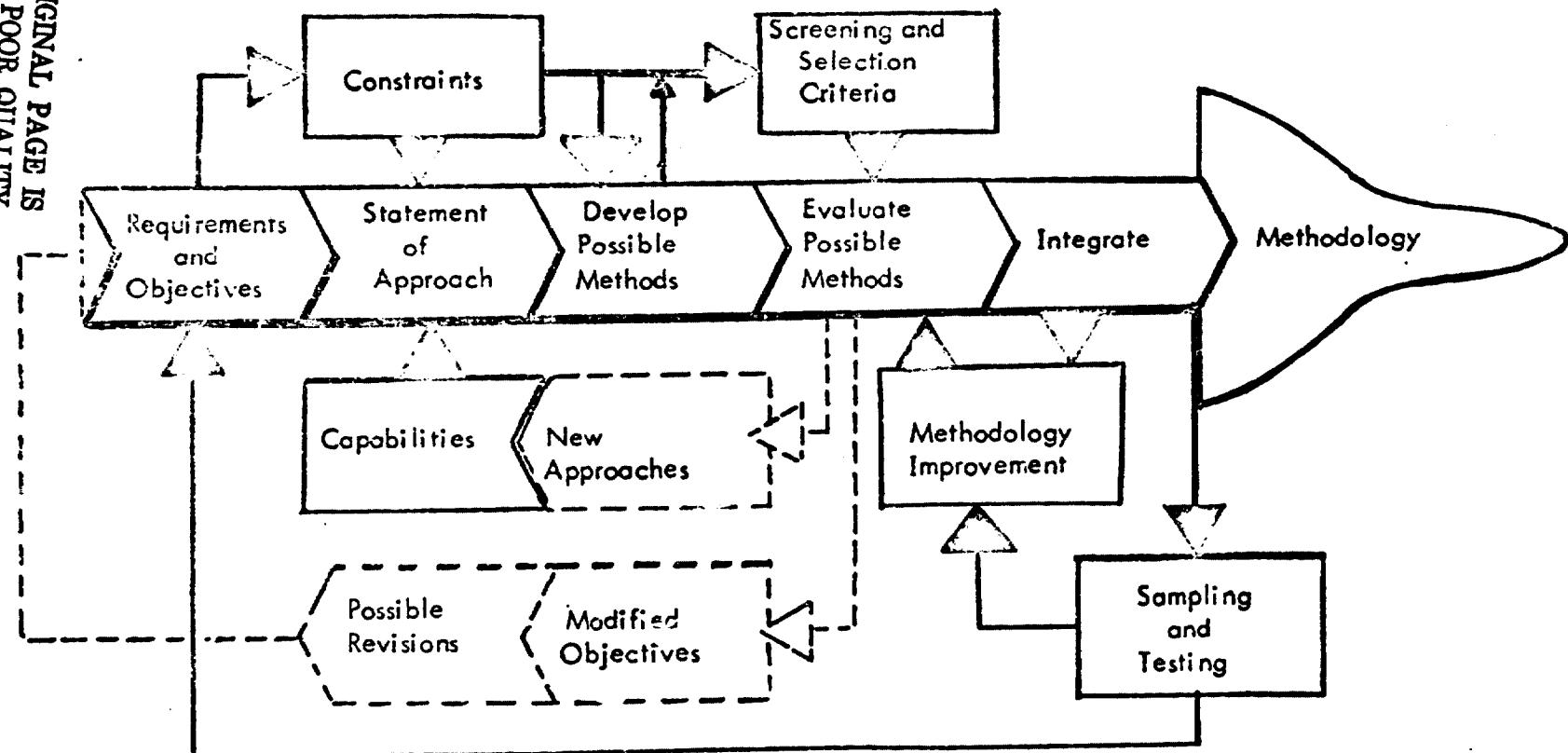
- TECHNICAL
- ECONOMIC
- USER ACCEPTANCE
- INSTITUTIONAL FACTORS



## SYSTEMS AND METHODOLOGY PLANNING

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26



## SUMMARY

- MAJOR DATA COLLECTION AND PROCESSING EFFORT IS NOW UNDERWAY
- A LARGE QUANTITY OF DATA IS NOW READY FOR ENTRY ONTO FORMAT SHEETS
- ADDITIONAL DISCUSSIONS AND DEFINITIONS ARE REQUIRED ON DATA USE FOR SYSTEMS ANALYSES

**SOLAR ENERGY PROGRAMS**  
**UAH CENTER FOR ENVIRONMENTAL AND ENERGY STUDIES**

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**Systems Analysis**

**DATA BANK DEVELOPMENT**

- Architectural
- Climatic
- Economic
- Equipment
- Materials
- Projects/Sites

**COMPUTER ANALYSIS**

**DATA REPOSITORY**

**TOTAL ENERGY ANALYSIS**

- Solar
- Wind
- Bioconversion

**REGIONAL APPLICATIONS**

- Remote Sites
- Self Sufficient
- Off-The-Shelf
- Do-It-Yourself

**Test and Demonstration**

**METEOROLOGICAL FACILITIES**

- Reference/Standards
- Calibration

**DATA ACQUISITION**

**MATERIALS & COMPONENTS TEST**

**SUBSYSTEMS TEST**

- Conversion
- Storage
- Controls

**SYSTEMS TEST**

- Solar
- Wind
- Bioconversion

**RESIDENTIAL RESEARCH**

- Bread Board Test
- Hybrid Systems Development
- Conservation/Recycling

**Educational Applications**

**FACULTY PARTICIPATION**

**STUDENT PARTICIPATION**

**COOPERATIVE EFFORTS**

- Universities
- Consultants
- Governmental Agencies
- Industry

**SEMINARS/COURSES**

**LECTURES**

**DOCUMENTATION**

- Reports
- Technical Papers
- Bibliographies

**EDUCATIONAL MATERIALS**

- Data Packages
- Source Books
- Exhibits/Displays